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RAPID TRANSIT STATION LOCATIONS AND
RELATED COMMUNITY DEVELOPMENT

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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS.	ii
LIST OF ILLUSTRATIONS.	iv
Chapter	
I. INTRODUCTION.	1
II. THE TRANSIT STATION AND ITS EFFECT ON COMMUNITY DEVELOPMENT.	3
Required Facilities	
Off-Site Facilities	
On-Site Facilities	
Factors Influencing Development	
Station Spacing	
Improved Transportation	
Noise	
Aesthetics	
Traffic	
Impact on Land Use	
Residential	
Commercial	
Offices	
Industrial	
Public	
III. PLANNING FOR STATION LOCATIONS.	20
Locating the Transit Station	
Site Requirements	
Estimating Station Patronage	
Estimating Surrounding Development	
Selecting the Optimum Sites	
Controlling Community Development	
Official Map	
Zoning	
Leasing of Transit Property and Air Rights	
Urban Renewal	
APPENDIX	43
LITERATURE CITED	47

LIST OF ILLUSTRATIONS

Figure	Page
1. Travel Time Diversion Curve	26
2. Partial Symbolic Transportation Network	30

CHAPTER I

INTRODUCTION

By 1980, the United States will have a population of almost 250 million. Three-fourths of these people will be living in urban areas. The ability of our large cities, especially within the central core, to function efficiently as centers of business, entertainment, culture, and education will depend upon the adequacy of their transportation systems. It is, of course, true that our large cities will serve these functions to some degree even with grossly inadequate access to the urban core. However, central core access will promote that quality of development which depends on region-wide drawing power. For these activities and services to flourish, they must be easily accessible to as large a portion of the population as possible. The automobile has largely built our cities and provides the primary circulatory device. Unfortunately, the metropolitan "body" is now getting too big for its low-pressure circulatory system.

As one remedy, many large cities are now giving attention to the development of rapid transit. In fact, eight North American cities already have operating rapid transit systems, three of which were built since 1950. In addition, three more cities have rapid transit systems under construction and several others are engaged in extensive studies.

With the development of rapid transit, consideration must now be given to its effect on community development. For this purpose, the

transit system can be compared to an urban freeway system. Since the stations are the only points of access to and egress from the transit system, they function much like an expressway interchange. The transit lines function only to connect individual stations. Thus, the impact of rapid transit will be related primarily to the locations of its stations.

The objective of this study is to help the planner and transportation engineer in outlining the basic considerations in locating rapid transit stations and to explore land use trends adjacent to station sites. In addition, suggestions are made for achieving a more compatible relationship between transit stations and abutting land uses.

In undertaking the research for this work, a review and analysis were made of existing literature related to rapid transit with particular attention to station planning. In addition, personal correspondence and interviews were carried out with appropriate authorities in the areas of transit, planning, and related fields.

Chapter II describes the basic rapid transit station facilities, analyzes factors influencing development, and determines the impact of a station on various land uses. In Chapter III, a program is recommended for transit station planning. This program includes the steps in planning for station locations and ways of controlling anticipated community development.

CHAPTER II

THE TRANSIT STATION AND ITS EFFECT ON COMMUNITY DEVELOPMENT

From its inception, rapid transit has had a marked effect on community development. In cities, where growth was limited by a dependence upon pedestrians and horses, transit was instrumental in opening new areas for urban expansion.

The influence of transit stations on community development is clearly shown in Boston where the basic pattern of urban growth was created by the railroad and its outgrowth, the rail transit system. Rapid transit stimulated high density residential, commercial, and industrial development in the central core. The first large scale wave of suburbanization was located near transit stations in outlying areas. High density tenement districts were built within easy walking distance of transit stations and became closely associated with public transportation (1).

The effect of rapid transit today can be seen in Toronto. From 1954 (when the transit system opened) until 1966, the appraised value of all land and facilities in Metropolitan Toronto increased by \$15 billion. Ten billion dollars or two-thirds of this increase occurred along the Yonge Street Subway (2). Property within two blocks of the subway doubled, tripled and in some cases increased as much as ten times in value. During the ten-year period from 1952 to 1962, tax assessments

in the districts contiguous to the Yonge Street Subway increased 45 per cent in the downtown area and 107 per cent in the uptown area from College Street to Eglinton Avenue. This represented a total increase of \$136 million. At the same time increases in tax assessments for the rest of the city averaged only 25 per cent (3).

This development did not happen by accident. It was the result of benefits associated with rapid transit stations. This chapter outlines the basic needs for transit stations and determines the factors which influence development. These development factors are then used to analyze the effect of transit stations on various types of land uses.

Required Facilities

The measure of success of a transit station is its ability to transfer large numbers of people from various transportation modes to the rapid transit trains. To do this properly, a number of facilities are required both off and on the station site. This section analyzes these facilities and their arrangement to determine the needs of the transit station.

Off-Site Facilities

The off-site facilities associated with transit stations are concerned with fast and convenient movement of people to and from homes and work centers. The required facilities are broken down into three modes of access and egress: automobile, feeder transit, and pedestrian.

Automobile. Automobiles provide the predominant means of access to transit stations in outlying areas. Therefore, these stations must be served by an adequate system of major arterials and expressways.

Since each two miles of automobile travel takes from five to ten minutes, the amount of potential patronage depends on smooth flowing traffic. The highway system should thus function similar to a river basin with the mouth at the transit station. Access traffic should be directed towards the point of destination, the downtown work center. In addition, the station must intercept traffic before it reaches areas of congestion on the highway. This shortens travel time and avoids patron frustration.

Feeder Transit. As transit stations are located closer to the city center, feeder transit becomes a very prominent mode of access to and egress from the station. The quality of this service also depends on the surrounding highway and street systems. The area served must have good traffic circulation with access to major crosstown arterials. Since feeder transit travel times increase greatly with long routes, most bus patronage originates within two miles of a transit station.

Pedestrian. In the highly developed areas, especially the downtown sections, pedestrian movement is the prime source of transit patrons. People do not like to walk great distances particularly in hot or inclement weather. Therefore, pedestrian movement is restricted to a maximum walking time of from five to ten minutes. When pedestrian traffic is heavy, facilities should be provided to separate it from vehicular traffic. This may require the construction of pedestrian overpasses or underpasses. In addition, sidewalks should be well lighted and have adequate police protection for night patronage.

On-Site Facilities

Even with excellent street and highway systems serving transit

stations, congestion develops unless smooth and convenient vehicular transfer is provided from the street system to the station site. Where possible, numerous access points should be provided to avoid concentrating vehicular movements. Since access to the transit station is limited to the traffic capacity of the street system, consideration should be given to ways of increasing street capacity. This can be done by constructing ramps, overpasses, or turning lanes and by installing signals.

Each mode of access will have different requirements for on-site facilities. Vehicles entering the station site should be separated according to their needs. Thus, automobiles using parking facilities should not interfere with vehicles using drop-off areas. This avoids congestion and results in a much faster handling of transit patrons. On-site facilities discussed here include parking, drop-off facilities, walkways, and station structures.

Parking. The parking requirements for transit stations vary from none to as many as 2500 parking spaces (4) depending upon the population density of the area served. As stations are located nearer to the city center, the requirements for parking decrease. This reduction results from the increased use of feeder transit and pedestrian access. In addition, increasing land value and displacee problems may raise the community cost of parking above the community benefit.

Where existing development makes the provision of large parking areas excessively costly, either a parking structure should be built or parking should be provided elsewhere. Some improved land must be acquired at almost any station site, so in a sense, land is never

readily "available." From a planning viewpoint the test is not simply availability. There are stations which predominantly serve nearby employment and commercial centers among which it would be undesirable to create a large "void" of land for parking even if it were available. That is, new office space or cultural facilities might be a more desirable or "higher" use.

All parking should be within 600 feet of the station platform to avoid long walks by patrons using automobiles (5). Aerial stations provide the best means for parking lot arrangements. Parking can be provided on both sides of the tracks with convenient access under the structure between lots. Direct access between parking lots is needed so that cars can move to another lot when one is full. A long drive around the site discourages some drivers and results in a lowering of transit patronage.

Drop-Off Facilities. Feeder transit drop-off facilities are provided by either turn-around bus loops or an additional street lane adjacent to the station site. Bus loops and layover space should be provided only where bus lines terminate at the station. Continuous bus lines function best when they can unload passengers without leaving the street. The indiscriminate use of bus loops only makes the transit system more expensive and increases travel time for many routes.

Drop-off facilities for automobile patrons should be provided wherever possible. Depending on the demand, these facilities can be loops or additional street lanes. The use of drop-off facilities reduces the parking requirements for a station by making it convenient for the wife to leave the husband at the station.

Walkways. Covered walkways should be provided for all pedestrian movement on the station site. These facilities should take pedestrians from pedestrian overpasses, parking lots, and unloading areas directly to the station structure. In laying out walkways, care should be used to avoid conflict with vehicular traffic.

Station Structures. All other facilities relating to transit stations exist to supplement the station structure. Station structures house the fare collection areas, escalators and stairs, boarding platforms, and various accessories appropriate to the site, such as building connections, retailing establishments, and eating areas. All stations have at least two levels, one for the tracks, and one for pedestrian access across the tracks. All station facilities should be arranged so as to provide easy access to the transit train.

Factors Influencing Development

Activities associated with transit station operations and the location of the station influence development in the area. This section identifies the influencing factors and explains the general effect of a transit station on development.

Station Spacing

Transit station spacing increases with distance from the city center. This results from the decreasing frequency of suitable access roads, the lessening population density, and the need for higher average speed for longer trips. When stations are too close together, less than 2,000 feet, operations of the transit system break down due to congestion along the lines. Moreover, the high cost of central area stations may

necessitate greater spacings with less overlapping of service zones. Thus, station spacing ranges from one to four miles in outlying areas and from one-half to one mile in built-up areas.

Improved Transportation

The greatest influence of rapid transit on development comes through improved transportation to the area. Inadequate transportation facilities and the resulting traffic congestion are detrimental factors in locating new development. New improvements, such as office buildings and retail outlets, are not successful without people. In Baltimore, for example, a major department store won a \$125,000 tax reduction in 1959 on the grounds that traffic congestion and lack of adequate transit service caused a deterioration of the downtown retail area (6).

The existence of a rapid transit station makes an area much easier and quicker to reach. Large numbers of people are consequently funneled through the properties adjacent to the station, thereby opening the area to a wide range of possible uses. The Cleveland Transit System has realized the importance of excellent transportation in the city center and is now planning a downtown distribution loop which will increase the work force served in the major business area from 21.3 per cent to 88 per cent (7).

To illustrate the effect of rapid transit, consider two blocks in the developed section of any large city. Providing other factors affecting urban land use remain constant, the value of both blocks will stabilize as traffic reaches the capacity of adjacent streets and may even decrease if serious congestion results. If one block is suddenly served by a transit station, land values will immediately rise. Due to

the large number of people channeled to the area, this block now has greater potential for improvement than the block not served by a transit station.

The effect of rapid transit is not restricted to the central city. The presence of a transit station will increase the growth potential of many outlying areas now restricted by lack of adequate access. Each mile of rapid transit brings suburban and rural land three years closer to development (8).

Noise

Noise results principally from the interaction of steel wheels and rails plus the aerodynamic turbulence around the wheels. Additional noise is generated by activities in and around the transit station. These activities include vehicular traffic, clean-up and service operations, such as trash and garbage collection, snow removal, and the sweeping of the parking lots. Maintenance activities are particularly offensive since they usually occur during the late evening and early morning hours.

The effect of noise on surrounding development depends upon the degree and kind of noise generated and the type of development existing or planned in the area. As the density of development increases and background noises are developed, the effect of transit noise becomes less pronounced. In most cases, noise has little effect outside the immediate area of the transit line. Because of the greater range of site activities associated with outlying stations these facilities usually have greater noise problems than do stations in built-up areas.

The adverse effects of noise can be reduced by placing buffer

areas around stations and by controlling the source of the noise. Steel-on-steel noise can be greatly reduced by using continuous rails, resilient pads, and by damping resonant vibrations in the rail web and wheel disc. Some experts consider the use of rubber tires desirable over steel wheels in certain situations, such as when sharp curves are involved (9).

Aesthetics

Aesthetics are, of course, a matter of taste. However, the transit station should at all times be as attractive as possible and blend with surrounding development. As with noise, downtown stations do not create a problem. The surface structures involved are usually small and many station entrances are located in existing buildings. The most serious conflict involves elevated stations. These structures have traditionally been ugly, massive, steel H-frame buildings. The detrimental effects of these structures can be seen in the Charlestown section of Boston where the elevated transit line caused adjacent business to move to new locations. Owing to its adverse effects on the community, the elevated structure is being removed in conjunction with an urban renewal project.

San Francisco is using more pleasing tee-frame concrete aerial structures to reduce conflicts with adjoining land uses. Under a grant from the Department of Housing and Urban Development, a 2.7-mile section under the aerial structure and stations in Albany and El Cerrito is being landscaped to provide parks serving neighboring residential development. The linear parks will contain illuminated walkways, landscaped mounds, shade trees, cover plants, and playgrounds. In addition, these

parks will connect with and supplement open space provided by such public uses as schools, a senior citizen's center, and a library (10).

Traffic

Increased traffic around transit stations can result in congestion for the whole area. The problem is that most patron usage occurs during morning and evening peak hours. This means that to avoid congestion, facilities must be over-designed for the rest of the day's demand. Since this is impractical, some slow and uneven flows must be tolerated on the major thoroughfares leading to and from stations during peak hours.

The most detrimental effect of increased traffic is that part of the overflow from the major thoroughfares will use local streets in the area to reach the transit station. Since these streets are normally not designed for this purpose, abutting residential property may be adversely affected. The situation can be corrected to some degree by dead-ending some of the local streets, thereby forcing the traffic back to the major thoroughfares.

Impact on Land Use

Rapid transit stations influence community development and help determine land use in a given area. This section discusses the effects of rapid transit stations on residential, commercial, office, industrial, and public uses.

Residential

Before the widespread use of passenger cars, transit served only pedestrians thereby restricting its influence on residential development

to a quarter mile radius of each station. With automobiles and buses serving as feeders, transit stations can now serve low density residential subdivisions. The resulting zone of influence extends to a radius of more than four miles. The presence of rapid transit often enables a suburban resident to cut his commuting time by a substantial amount. This reduction in commuting time increases the value of his residential land relative to other areas of the city. Studies undertaken in the San Francisco Bay Area indicate that single family residential properties increase in value by approximately \$1,500 for every reduction of ten minutes in commuting time to the major employment center (11).

A rapid transit station opens new areas for residential development. This development increases land values many times and often makes profitable the draining and development of areas previously unfit for habitation. Land values increase in these areas as soon as the location of the transit line is established.

Low-density residential development does not normally locate immediately adjacent to transit stations. The presence of the transit facility itself and the increase of vehicular activity in the area make the location undesirable for single family residences. However, apartment construction can be expected adjacent to outlying transit stations. These locations appeal to people who like apartment living but do not wish to reside in the city.

Development of this type is already taking place in Southern New Jersey where the Delaware River Port Authority is currently constructing a rapid transit line connecting the area with Camden and Philadelphia.

Sixty-four apartment units have been built in Ashland and 80 in Kirkwood. In addition at least three other apartment projects are now under construction in the area (12).

In built-up areas of the central city, a heavy demand develops for the limited amount of land with primary access to transit stations. The resulting high value of land immediately adjacent to the station leads to the conversion of low density residential property to some more profitable land use. In Toronto, for example, many people who bought modest homes at \$15,000 to \$25,000 each before the arrival of a transit station, later sold them to apartment developers for \$50,000 to \$75,000. Hundreds of large residential lots, 175 feet by 200 feet in depth, were subsequently rezoned to accommodate high-rise apartment buildings in the vicinity of transit stations (13). Similar rezoning has taken place in Philadelphia and other American cities.

Downtown apartment developments and transit stations are complementary. Since this type of residence usually attracts office workers, quick and convenient access is required to centers of employment. Rapid transit provides this service. Consequently, areas within walking distance of transit stations provide suitable locations for high-rise apartment complexes. Although land costs are high, the increased accessibility provided by the site is worth the cost. For example, during the five-year period between 1959 and 1963, 48.5 per cent or 4,130,000 square feet out of 8,512,000 square feet of all high-rise apartment development in Toronto occurred in four planning districts served by the Yonge Street Subway (14).

The primary mode of access to transit stations in high density areas is by walking. Therefore, the range of station influence is limited by the distance covered in a five to ten minute walk. Because of the limited area available and the great benefits derived from locations adjacent to transit stations, the development of transit station air rights for apartment complexes is now taking place in several cities including Toronto, Montreal, and Cleveland.

Commercial

Rapid transit provides the stimulus for revitalizing retail trade in the central business district. The reason for this is that direct access is provided to the central city without increasing vehicular traffic and congestion. Suburbanites can thus return to the central business district to enjoy the entertainment, convenience, and selection of downtown shopping. As more apartments are constructed next to transit stations, thousands of wealthy customers are pipelined into the downtown area, furthering its economic potential.

For retail trade, locations near a subway station are desirable. The benefit of these locations results from their proximity to a greater concentration of people as compared to other sites in the downtown area. Thus, land values are highest adjacent to the transit station and taper off as the distance from the station increases. Beyond a ten minute walk the beneficial effect of the station is no longer felt, and locations farther away may even decrease in value.

A decrease in property values midway between transit stations sometimes results from the change in travel patterns caused by the subway. Some merchants are completely separated from the main stream of

activity with a corresponding loss of business. This trend was evident shortly after the subway system was opened in Toronto (15). However, this loss in business does not take place when a large traffic generator is placed between transit stations. This helps draw people through areas which otherwise might lose their vitality.

Commercial uses compatible with outlying stations are convenience shops, such as drug stores, barber shops, small grocery stores, and liquor stores. These businesses are used extensively by commuters doing last-minute shopping on the way home. It is important that they be readily accessible to commuters. These shops should be either part of the station structure itself or located in the immediate vicinity. Garages and service stations located adjacent to the parking lots could serve commuters leaving their automobiles to be serviced during the day.

Shopping centers and other large traffic generators should not be located adjacent to the station site. The traffic involved with these uses would congest the access streets to the station, and their patrons might use parking space needed by transit patrons. However, if these facilities are a short distance from the station, they can serve patrons without adversely influencing the efficiency of the transit station. This type of commercial center is convenient for the wife in a one-car family when she drives her husband to the station, and shops en route.

When a transit station is located in the center of an existing outlying commercial area, local business receives an economic benefit even though stores are old and run down. This increased business

potential stimulates firms to upgrade their stores. However, businesses which do not have adequate and pleasant pedestrian access from the station will deteriorate further. Thus, existing small commercial centers must plan for the proper utilization of transit stations. This type of planning is now being undertaken in several San Francisco area suburbs (16).

Offices

Rapid transit creates new sites for office buildings. The improved transportation provided by transit to other sections of the city has enabled office developments to locate adjacent to transit stations outside the central business district.

A location near a transit station enables the construction of a far more economical building. This results from a lessening demand for parking. The space previously needed for parking can now be used for additional office space if zoning ordinance parking requirements are suitably amended. In San Francisco, for example, the 43-story Wells Fargo building was recently completed with no provisions for parking facilities. The building will depend upon rapid transit for its access needs. A direct entrance to a nearby subway station is being planned (17).

The impact of new office construction can be seen in Toronto where between two and three million square feet of new office space are being constructed within walking distance of stations along the Yonge Street Subway. In fact, between 1959 and 1963, 90 per cent of all office construction, or 5,036,000 square feet out of 5,585,000 square feet, occurred in three planning districts contiguous to the subway (18).

The location of office buildings away from the central business district has a subsequent beneficial effect on the transit system. These buildings generate reverse direction travel during rush hours, thus improving operating efficiencies.

Industrial

The existence of a rapid transit station could have marked effects on an area's industrial development. The location of transit stations in the outlying suburbs will open new areas for industrial land uses. Firms which had been confined to the central city because of their dependence on low-income labor might now move to more spacious locations. Conversely, the renewed vitality of the downtown areas might draw many industries back to the central city. The result will enhance the overall industrial outlook for the entire urban area.

Planned industrial districts could benefit from a location close to a rapid transit station especially for those industries employing large numbers of people. In addition to the convenience provided the employees, the companies will benefit from reduced parking requirements and a reduction in traffic problems at shift changes.

Industries with large physical plants and relatively small numbers of employees should not be encouraged to develop near transit stations. These plants will not induce much patronage to the transit system while, at the same time, they take up large quantities of land which could be developed for some more complementary use. However, large plants should be located near enough to a transit station so that feeder transit could be provided between the plant and the station during rush hours. If properly developed, industrial land uses in the vicinity

of transit stations could have the same reverse direction flow effect as outlying office developments.

Public

One of the major concerns in locating public uses, such as stadiums, urban colleges, and other transportation terminals is accessibility and parking. A location near a transit station provides direct, convenient access which attracts considerable numbers of people. This change in travel mode (from automobile to pedestrian) reduces the parking requirements at the site. At the same time traffic congestion around the public facility will be reduced, thereby making this area more advantageous for other development. Historically, however, planned but unbuilt transit systems have had little or no influence on the location of public facilities, e.g. Atlanta Stadium, Pittsburgh's new stadium, and the Oakland Coliseum.

CHAPTER III

PLANNING FOR STATION LOCATIONS

In planning for transit station locations, two items must be considered: the function of the station and the character of surrounding development. Transit station functions are classified with respect to the morning peak hour work trip. Collector stations serve the home end of commuter trips and are usually located near centers of population. Distributor stations, on the other hand, serve the work end and are located near centers of employment. However, this distinction is not clear cut as some stations serve both functions. The site requirements of each station location depend on its function with respect to the transit system.

Since transit stations attract many uses to the station area, buildings tend to be larger and higher than those existing previously at the location. High standards of access and circulation are needed to insure orderly development. In downtown areas, pedestrian movement should be emphasized because transit facilities reduce dependence on private vehicles.

Locating the Transit Station

Properly locating stations is most important in developing a transit system. Transit line locations should be subordinate to the location needs of the station. In fact, the line's primary function is to connect individual transit stations. When choosing station locations,

consideration must be given to site requirements, patronage, and potential development at each location. These aspects are all important and every effort should be made to optimize each requirement.

Site Requirements

The major criteria for selecting transit station sites are the number of riders and the means of access. These factors determine its size and shape. Topography and soils are usually considered as pre-existing conditions and affect site selection only when high costs are required to overcome their adverse effects. Moreover, a site should enhance or at least preserve surrounding values and uses.

Size. The size of outlying stations varies considerably, depending on the needs for parking and feeder transit facilities. A minimum size of one acre is needed to provide for the station structure, feeder transit facilities, and other station operations. To estimate the additional area required for parking, a gross area figure of 475 square feet per parking space may be used (19). Data from the Cleveland and San Francisco systems indicate that from 30 to 50 per cent of transit station patrons arrive in a parking automobile. Since two to three hundred spaces are required for efficient operation of parking lots, station sites providing parking should range from 3 to 15 acres. For parking area requirements in excess of 15 acres, parking decks may have to be employed to reduce walking distances.

Downtown stations need considerably less land due to the absence of parking lots and the predominance of pedestrian access. At some stations land is needed for feeder transit facilities, but in most cases the station should require no more than one acre (20). A larger space

may be needed because of non-transit considerations, such as development of needed open space, e.g. Place Ville Marie in Montreal, or because the automatic train control center must be centrally located, or both, e.g. Lake Merritt Station in Oakland or Transit Center planned in Atlanta.

Shape. The shape of collector stations is important because of its effect on the efficient use of land for parking and on the walking distance required to reach the transit trains. Irregular shapes, especially those with small acute angles, should be avoided because much of the land will be unusable for parking and therefore wasted.

Where parking can be provided on both sides of the tracks, a square-shaped site is best. Locating the transit station in the center of the site results in the shortest walking distance from all points. When parking is restricted to one side of the tracks, the site should be rectangular with the long axis along the station platform.

Subway stations require only a rectangular underground easement along the transit tracks. This provides for the platforms and other station facilities. In many cases, the limited need for above ground facilities enables the surface site to be adjusted to fit available land.

Topography. Topography is important only for stations depending on vehicular access. These stations should have relatively level sites with no abrupt changes in topography. Steep grades would adversely affect the maneuverability of buses and some passenger cars. However, sufficient slope is needed to provide proper drainage.

Major earth movement is usually not expensive when weighed

against higher land costs on level sites. However, major site grading may be aesthetically undesirable, or may fail to solve the problem of getting good access into the site.

Soils. In general, any soil which is suitable for the construction of the transit line will be suitable for transit stations. For stations with parking, the area should have good sub-base drainage to avoid deterioration of the pavement. For downtown subways the best soil would be solid bedrock or stiff impermeable clay. This enables the station to be bored along with the rest of the transit line.

Estimating Station Patronage

As long as good access is provided, the determination of patronage is probably the most important element in locating transit stations. Except for construction costs, all elements of the system are based on patronage; revenues, operating costs, design, level of service, and most important, justification for the system itself. This section discusses the studies used to determine travel characteristics and outlines the steps used to forecast transit station patronage.

Origin-Destination Survey. The basic data for estimating patronage are derived from a metropolitan area origin-destination survey. This survey employs a combination of interviews and person-trip volume counts to determine travel habits, points of origin and destination, and trip purposes.

In conducting an origin-destination survey, the first step is to divide the metropolitan area into small zones. Each zone should be as homogeneous as possible. The division into zones should be made with respect to land use, population characteristics, topography, etc.

This will enable the use of average figures to represent the characteristics of each zone.

A "cordon line" is then established around the downtown area of the city. The downtown is singled out because rapid transit is oriented toward downtown trips. Thus, the "cordon line" should separate this commercial and office area from surrounding residential areas. However, the "cordon line" must be so located that traffic crossing the line can be easily counted. Rivers, railroads, and expressways which are perpendicular to the downtown traffic flow make ideal locations for "cordon lines."

The major source of origin-destination information is the Home Interview Survey, in which a controlled sample of dwelling units within the "internal area" (area enclosed by the "cordon line") is selected and the occupants interviewed. Expansion of the sample interviewed in this survey simulates all travel made by residents of the "internal area." This information consists of travel origins and destinations by zone, the purpose of trips, and household characteristics, such as age, income, and the number of automobiles and drivers.

The Home Interview Survey is supplemented by the External Survey, consisting of roadside driver interviews and vehicle counts along the "cordon line." In expanding the External Survey sample, all trips recorded as being made by residents of the "internal area" are normally omitted, since these would duplicate trips sampled in the Home Interview Survey.

Sample sizes are determined by individual study requirements. A uniform 5 per cent Home Interview Survey sample size has been normal

for metropolitan area transportation studies although there now seems to be a trend toward varying the sample size to assure adequate sampling of zones with low population density. External Survey sample size usually varies inversely with the volume on the road being sampled, and may range upward from a minimum of 5 to 10 per cent.

The number of "transit-certain" riders, people who have no choice but to use mass transit, is now determined for each zone. Since these patrons are forced to use transit, further analysis is not needed for this segment of person-trips. It is necessary to recognize that the number of such person-trips declines with increasing prosperity and to project the downtrend.

Transit Versus Automobile Travel. The major measure of rapid transit attraction is its savings in door-to-door travel time. Since actual data on potential rapid transit riders are not available in a community that now lacks rapid transit, initial studies must be based on comparisons between bus and automobile travel.

A relationship is developed which measures the tendency to use transit for those riders who have a choice of transportation mode. This tendency is expressed graphically by means of a travel time diversion curve, which measures the attraction of transit, in per cent of potential riders, with respect to its savings in travel time over the automobile. A typical diversion curve can be seen in Figure 1. Separate diversion curves are developed for each of the various classes of potential riders. Thus, curves are made for those who travel on peak and off-peak periods, CBD and non-CBD trips, and work and non-work trips. This breakdown enables patronage estimates to be made for various times

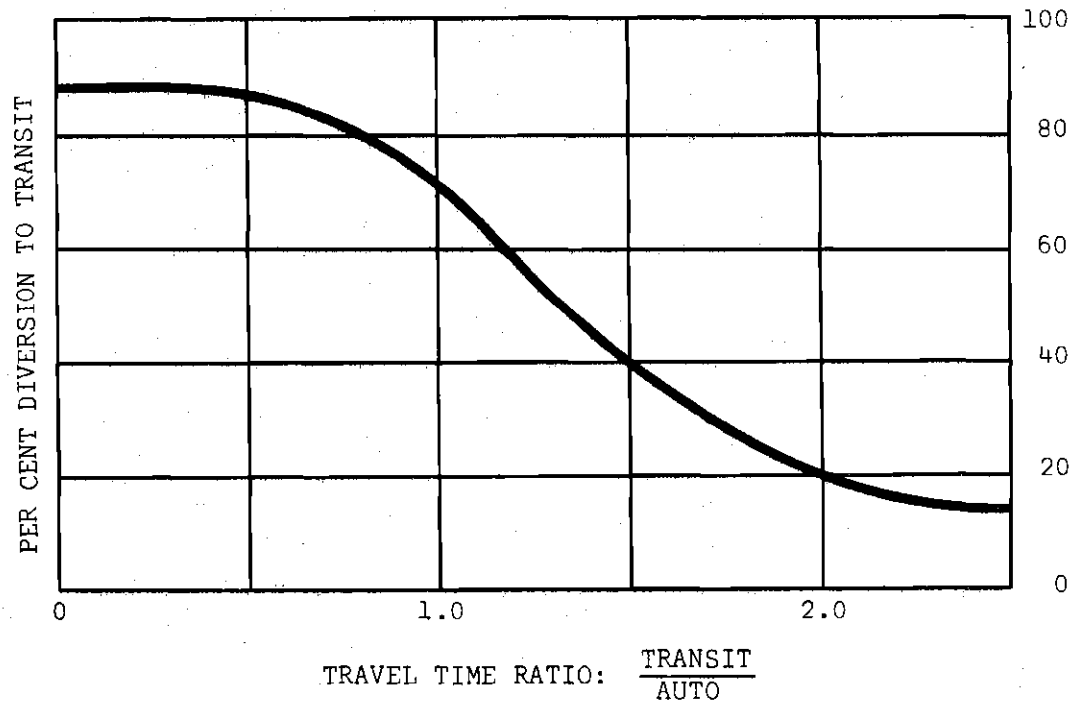


Figure 1. Travel Time Diversion Curve

of day, destinations, and trip purposes. Each diversion curve represents the average condition for the entire metropolitan area.

The first step in developing travel time diversion curves involves estimating the door-to-door travel time by each mode of travel between zones in the origin-destination survey. Estimates should be made for both peak and off-peak periods as well as for CBD trips and non-CBD trips. Travel times for mass transit are computed from local transit system schedules and those for automobile are measured in the field or obtained through state or local highway departments. All feeder time, transfer time, and waiting time should be included in these computations.

Travel time ratios are then computed between transit and automobile for each zone-to-zone trip. A travel time ratio is a number expressing the travel time by transit relative to that by automobile. This relationship is computed by dividing the travel time for a trip via transit by the travel time for the same trip via automobile. Thus, a travel time ratio of 2.0 means that travel via transit takes twice as long as travel by automobile.

The next step consists of plotting the travel time ratio for each trip against the percentage of travelers using transit. These percentages are computed from the volumes obtained during the origin-destination survey. When all the points, one representing each zone-to-zone trip, are plotted, the travel time diversion curve is formed.

Finally, the travel time diversion curve should be modified by comparison with similar curves representing cities which have existing transit systems. This comparison is needed because rapid transit may

affect rider habits differently than bus travel. Since bus trips usually take longer than automobile trips, data from existing rapid transit systems must be adapted to supply data for travel time ratios of less than 1.0.

Preliminary Station Locations. Preliminary station locations are selected on the basis of population and employment density. Several general location areas are selected near the centers of population or employment. For collector stations, consideration must be given to their convenience to transit-certain riders. The spacing, access, and site requirements mentioned previously are now applied to select several possible station sites within each general area of population or employment concentration. Each site is now analyzed to determine its potential patronage.

Delineating the Service Area. The service area is outlined for each possible location. Each service area includes several of the zones used in the origin-destination survey. Collector stations in outlying areas need a service population of up to 75,000 people (21). This relatively large population requirement results from the low percentage of people in these areas working in the central city. Moreover, many people who would need an automobile for access to the transit station feel that once in the car, they are better off driving straight to work.

The density of population is not important as long as the street and highway system in the area provides adequate access to enough people. In Cleveland, for example, some transit stations are serving areas with population densities as low as two persons per acre (22). Low population densities in outlying areas require service areas extending more than

four miles from the transit station.

Collector stations nearer to the city center require smaller service areas. These areas are characterized by higher population densities and a predominance of feeder transit and pedestrian access to the station. Because of the concentration of transit-certain riders, stations in built-up areas can function with a service population of less than 50,000 people (23).

The service area for distributor stations is dependent upon employment in the area. Distributor stations should be located as a group to achieve the best possible transit access to the downtown area. Since these stations depend on pedestrian access, the service area is limited to a radius of one-quarter mile.

Patronage Forecasts. In figuring patronage for each alternative station site, the travel time via transit and the travel time via automobile must be determined for each zone-to-zone movement. The hypothetical rapid transit system and the existing and proposed highway systems are used to compute these travel times. As with the derivation of the diversion curves, both travel times are computed door-to-door including, where applicable, feeder, waiting, walking, and parking times.

The advent of the electronic computer makes possible a thorough analysis of patronage in an exceedingly short time. To accomplish this, a symbolic network of links and nodes is used. This network provides for both transit and automobile travel between all nodes. A partial symbolic transportation network can be seen in Figure 2.

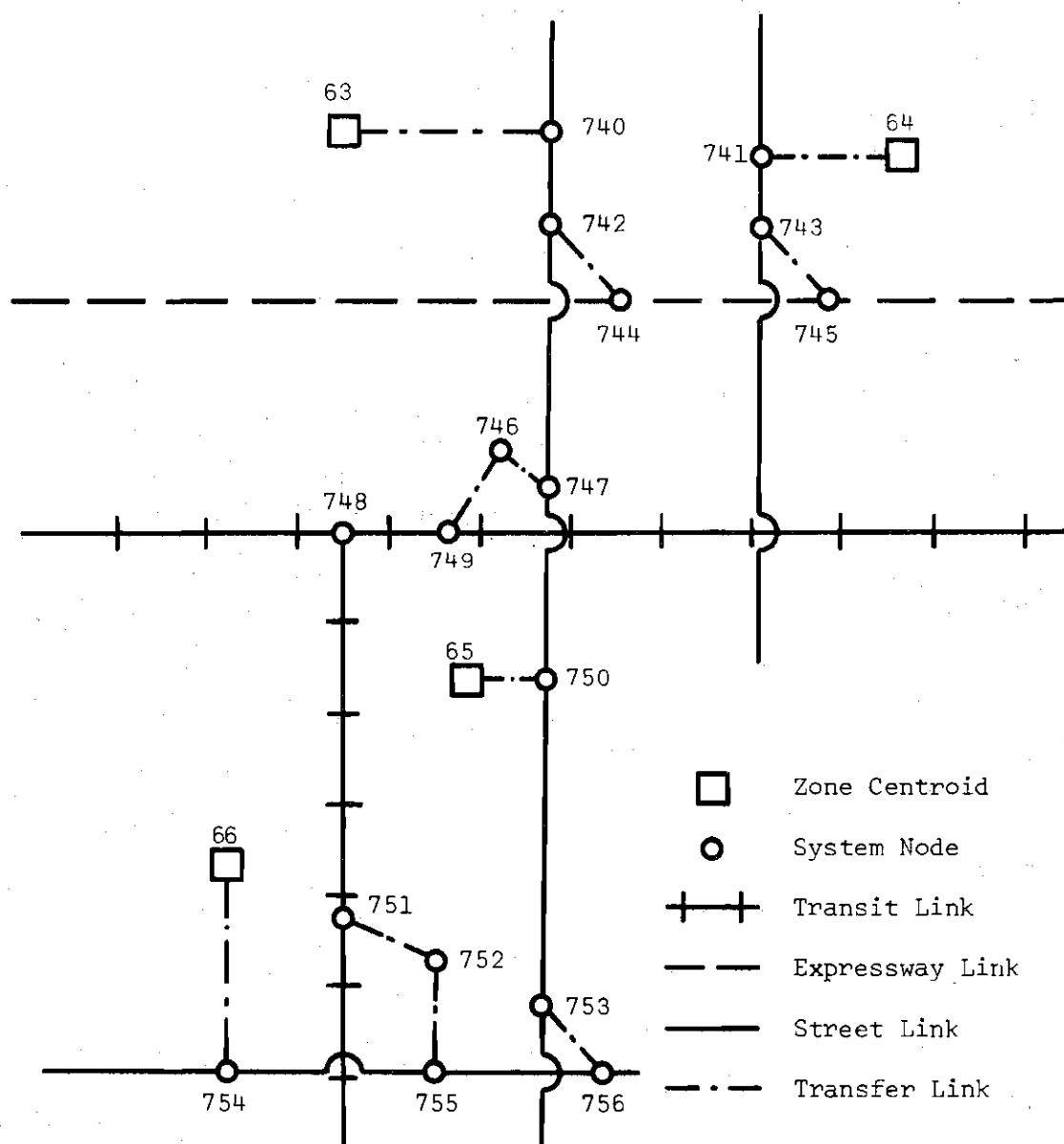


Figure 2. Partial Symbolic Transportation Network

A link is a section of the network defined by a node at each end. Each link is identified by the code numbers of the two nodes it connects and has a given travel time and distance. For example, in Figure 2 transit link 748-751 might represent a travel time of 40 seconds and a distance of one-half mile.

A node is a point representing the intersection of two or more transit routes, highways, or points of access to or egress from the transit or highway systems.

A zone centroid is a type of node which is assumed to represent the origin or destination of all trips bound to or from a zone. Thus, this analysis deals only with average figures for each zone. For example, the access time to a transit station is considered the same for all trips from the zone.

The computer calculates minimum travel time paths from each zone to all other zones and the total time required to make the trip for both transit and automobile. Separate travel times are computed for different trip purposes, time of day, and destinations.

Travel time ratios are determined for the various trips using each alternate station site. The ratios are applied to the travel time diversion curves to compute the percentage diversion to transit for each alternative. Transit patronage for each site is determined by applying the percentage diversion to transit to the volumes derived from the origin-destination survey. To this figure must be added the transit-certain riders for each alternative site.

For down distributor stations, other methods are sometimes used to supplement the diversion curve analysis since the patron's choice of

station is not as sensitive to time as is the computer program. In Washington, estimates are based on the total employment in the service area, the percentage of employed absent, the percentage of employed walking to work, the amount of parking in the area, and auto occupancy (24). Under this system:

$$TTT = EMP - (a+b)EMP - P(AO)$$

where,

TTT = Total transit trips

EMP = Total employment

a = Percentage of employed, absent

b = Percentage of employed walking to work

P = Number of parking spaces

AO = Auto occupancy

This represents only the minimum patronage for each peak period but is useful in comparing alternative locations.

Estimating Surrounding Development

When estimating anticipated development surrounding transit stations, the potential development of the whole community is considered. The goal of the community should be to maximize its total growth rather than enhancing the value of any one area. Therefore, a population and economy study should be conducted for the entire community. In making these forecasts, consideration must be given to the success rapid transit will have in attracting new business and industry to the area.

The results of these studies will indicate the amount and type of development that is available for the areas surrounding transit stations. Examples of this type of planning can be seen in the San Francisco-Oakland metropolitan area where El Cerrito has already re-drafted its master plan to take full advantage of the two transit stations to be constructed there. In addition, Walnut Creek is using its station as the impetus to develop its central business district in a northerly direction (25).

When analyzing the development potential of individual station sites, the following studies should be performed. The area covered by the analysis will vary from as much as a one-mile radius at the outlying sites to as little as the adjacent two or three blocks at downtown sites.

Land Use Study. A land use study should be conducted around each potential station site. This establishes the type of development suitable for the area and the ease with which this development can take place.

The greatest development potential will occur at locations where little existing development is encountered. Even though an existing type of land use may not be compatible with a transit station, the cost of replacing this use could override the benefits of transit. Similarly, where large cemeteries, lakes, and other non-changeable uses are encountered, the full effect of the transit station can not be realized because of the reduced amount of developable land. However, note must be made that success breeds success. Once the conversion of land use starts, the entire station area will undergo this transformation, no

matter how dense the existing development. For example, Montgomery Station in the financial heart of San Francisco will soon be completely surrounded by major new structures.

In those areas where development has occurred, older areas will be influenced more than new ones. The removal of property near the end of its economic life and other marginal uses will be easier than the removal of new high value development. Low density residential uses close to the central core will probably not present a problem regardless of age.

The size and shape of existing parcels influence development. High density residential, commercial, and industrial uses require large parcels of land. The assembling of small residential lots into suitable parcels for development may be difficult and thus retard development in the area. Therefore, a careful study of platting patterns and ease of purchase should be made in the vicinity of each potential site.

Topography plays an important part in determining development patterns in less densely developed areas. If grades are consistently more than 5 per cent, little large-scale commercial or industrial development takes place because of the high cost of grading. These areas should be used for residential purposes.

In addition to a study of topography, a study of soil conditions is very important. The type and density of construction are determined by soil conditions. When certain silt and clay soils are present or where the water table is high, the high cost of foundations forces low density land uses for most areas. However, this high cost of construction can be overcome as the amount of developable land near

transit stations decreases.

Public Services Study. Since high density development can not take place without a great demand on utilities and other community facilities, such as fire and police protection, a study should be made of the adequacy of public services at each alternative station site. This study should include an inventory of what exists, a determination of future needs, and the costs for needed improvements.

Of greatest importance in this analysis is the study of thoroughfare needs in the area. Adequate thoroughfares are required to insure convenient traffic circulation. The amount of new street and highway construction required thus has a great bearing on the desirability of each site.

Development Forecasts. Development forecasted by the community population and economy studies is now assigned to the areas of station influence. The allocation of this development should be based on the desirability and potential of each location as determined by the land use and public services studies. Future population and employment estimates are based on the development allocated near each site. These figures are the basis for predicting the future adequacy of each station site.

Selecting the Optimum Sites

The final selection of transit station locations for the system must be a compromise among optimum patronage, site accessibility, peak operating efficiency, and ideal future development patterns for the community. Estimates for future patronage at each possible site are made based on the development projections in the area of influence.

These figures are compared with the estimates for present patronage to obtain the best overall station locations.

Controlling Community Development

Increased development takes place in the vicinity of transit stations as soon as their location has been established. Therefore, stimulating development is not as important as controlling and coordinating building construction.

The first step is the preparation of a development plan for each station area. This guide for physical improvements must reflect a balance among land use, accessibility, and circulation. Since the station itself will attract the greatest number of people, the location of other large traffic generators should be very carefully controlled.

In downtown areas, the amount and density of new development and the volume of retail sales are directly proportional to the traffic to and from the closest transit station (26). Therefore, large pedestrian generators should be located so that they will draw people through the area adjacent to the station. On the other hand, large traffic generators near outlying stations should be located so that they will not cause vehicular congestion around the station site.

Numerous techniques are available to influence and control land use but no one can do the job alone. Careful analysis should be made of conditions at each site before applying any land use control. The following are the principal controls useful for transit station areas. Although each offers a partial solution, land development will be more coordinated if the controls are used to complement each other.

The Official Map

An official map prevents the erection of buildings and other structures within a proposed right-of-way. The purpose is to reserve this land until such time as the community is in a position to acquire it.

This tool can be very helpful in reserving land for transit stations. As soon as station locations have been determined, a map should be prepared showing the locations and boundaries of each proposed station site. This map is then adopted by the proper governing body to become official. From that time on no building permit can be issued for construction within the mapped area except in unusual situations. Some people feel the best use of official maps is to encourage the public to cooperate, and to assure the public agency an opportunity to thwart the selfish by acquiring property.

Zoning

Zoning is the division of the community into districts in which are regulated land use, set backs, height and bulk of buildings, density of development, and off-street parking.

The proper use of zoning is essential if the most desirable uses of land are to be obtained around transit stations. Density restrictions are critical. The higher the density permitted, the greater the value of the property and the more intense the development. For example, land where permitted construction is limited to one-time coverage, as much floor space as land area, can be bought in Toronto for \$3 per square foot. When the permitted density of this land doubles, the value more than triples to \$10 per square foot (27).

Density restrictions are critical when considering the development of air rights. Due to the great cost of providing foundations and supports over transit facilities, a large building is required to make the project economical. Thus, when considering development adjacent to transit stations, floor area restrictions must be relaxed to achieve proper land uses. The increased concentration of people in the area is justified because of the ease of transport provided by rapid transit.

The Transit District. One way of achieving desired development is adopting transit station zoning districts. These districts encourage large planned unit developments. Acceptable land uses are judged on their compatibility with and their need for a transit station location. All construction within a transit district should have greater floor area ratios than would be normal without transit for that area of the city. At the same time requirements are placed on the number of building entrances, sidewalk widths, plazas, and connections between streets. These facilities are needed to ease the great amount of pedestrian movement in the area.

Floor Area Bonuses. Where special transit station zoning districts are not desired, bonus floor areas can be given for certain development within existing districts. The bonus floor area is added to the normal floor area for the district and thus allows higher densities surrounding transit stations.

All increases in allowable floor area are contingent upon the provision of certain building features. For example, a recently proposed revision to the San Francisco Zoning Ordinance recommends a 20 per cent increase in allowable floor area with the construction of a

direct access from the building to a transit station (28). The quantity of bonus floor area for other features, such as proximity to a station, multiple building entrances, and sidewalk widening, can be seen in Appendix A. These bonuses are based on a downtown floor area ratio of 16 to 1.

When establishing a system of bonus floor areas, certain principles must be considered. First, the purpose for the bonus should be clear and each building feature for which a bonus is given should be suited to the needs of the area. Secondly, the quantity of the bonus must be properly scaled. For example, if the bonus is not enough, the desired building feature may be economically unfeasible and thus not provided. If the bonus is too big or if there is no upper limit when a sliding scale is used, the additional floor area allowed will be out of proportion to the public advantage of the feature provided. An upper limit is very important when two or more bonus features are used. Lastly, the basic permitted floor area ratio must not be so high that the bonus will rarely, if ever, be used.

Leasing of Transit Property and Air Rights

In providing for a transit system, land is often acquired which is not needed exclusively once construction is complete. This land, especially when located near a station and used in conjunction with air rights over transit facilities, may be ideal for high density development.

Through transit system or public ownership of this land, a great deal of control can be exercised over development. The land or air rights are then either sold to developers or leased on a long-term basis.

Leasing is beneficial to some developers since no large sums of money are required for land acquisition. The only cash outlay is the annual rental to the transit system. In all real estate dealings, the rights, privileges, and responsibilities of developers should be carefully defined.

The Montreal City Council recently adopted by-laws dealing with the occupancy and construction of building development on transit system air rights. In addition to completing the building within a specific time limit, the successful bidder must agree to the following conditions:

- a. A certain amount of space on the ground floor and in the basement must be made available for the use of the transit system.
- b. Development on the site shall be arranged to accommodate the required bus drop-off facilities for each station at the cost of the builder.
- c. There shall be the fullest cooperation with transit authorities so that the project will be perfectly integrated with the transit system.
- d. Regulations concerning the arrangement of shops shall be followed in all respects (29).

The lease agreement itself can also be used to control development. Among other restrictions, the lease should require the developer to state his development proposals before the lease becomes final. The transit system would have the right to reject the proposal based on its compatibility with other development in the area. Excerpts from the Toronto Transit System's lease agreement may be seen in Appendix B.

Urban Renewal

The urban renewal approach involves public acquisition of land. The land is then resold with stipulations requiring all development be in accordance with a specific plan for the area. This technique is helpful for the redevelopment of transit station locations where blight, premature subdivision, clouded titles, tax delinquencies, etc., have made large developable areas unmarketable.

There is great benefit to the community in coordinating urban renewal projects with transit station development. Besides making large tracts of land available for development compatible with transit stations, the coordination of station planning and urban renewal will help in the resale of land by the renewal agency. In addition, the total cost of transit construction is reduced since land from project areas is used for transit stations and right-of-way.

In Montreal, transit construction and urban renewal were coordinated to consciously affect land use. The transit stations were used as an instrument for reshaping and improving the central city. Instead of having the subway lines follow the main traffic and business arteries, they run beneath secondary streets. The policy was adopted to enable the city to widen and improve these narrow streets and revitalize the older rundown areas (30).

The future of our cities depends on improved transportation. If rapid transit is to be part of this improvement, planners and transportation engineers must understand the basic relationships between transit stations and community development. This thesis has attempted to explore these relationships and to lay the groundwork for transit

station planning. However, a great deal of additional research and analysis are needed. It is hoped that this work has aroused enough interest in this field to inspire others to continue this work.

APPENDIX

APPENDIX A

PROPOSED SAN FRANCISCO ZONING ORDINANCE

QUANTITY OF BONUS FLOOR AREA FOR EACH BUILDING FEATURE PROVIDED

BUILDING FEATURE	UNIT OF FEATURE UPON WHICH BONUS IS BASED	SQUARE FEET OF BONUS FLOOR AREA PER UNIT OF FEATURE				MAXIMUM FOR THIS BONUS (PER CENT OF BASIC ALLOWABLE GROSS FLOOR AREA)
		DOWNTOWN OFFICE DISTRICT	DOWNTOWN RETAIL DISTRICT	DOWNTOWN GENERAL COMMERCIAL DISTRICT	DOWNTOWN SUPPORT DISTRICT	
1. Rapid Transit Access	Larger of these two bonuses applies	Provision of direct access to station mezzanine				20
2. Rapid Transit Proximity		Each linear foot by which walking distance to station mezzanine is less than 750 feet --				10
3. Parking Access		100	100	100	100	5
4. Multiple Building Entrances		10,000	10,000	7,000	5,000	5 (or one entrance, whichever is greater)
5. Sidewalk widening		7	7	6	4	15
6. Shortening Walking Distance		40	40	40	30	10
7. Plaza		10	8	8	6	15
8. Side Setback	Larger of these two bonuses applies	6	6	6	3	15
9. Low Coverage at Upper Floors		Reduction of both building dimensions by 20% or more of the lot dimensions				15
		5% of basic allowable gross floor area for the first 20% reduction of building dimensions; 1% for each 3% reduction thereafter				

APPENDIX B

TORONTO TRANSIT SYSTEM LEASE AGREEMENT

Paragraph (1) Advance Rent:

The Lessee agrees to deposit with the Lessor the sum of (equivalent to three years' rent) on the execution of this lease, to be retained by the Lessor as security of due performance by the Lessee of the construction terms of this lease.

Paragraph (13) Description of Development:

The Lessee hereto covenants and agrees to develop at its own expense and without cost to the Lessor on the lands here in demised by such construction and buildings as are necessary to produce a development to the design and layout set out on the reproduced (sketch, photograph, or plans) annexed hereto as Schedule "B".

Paragraph (14) Time of Construction:

The Lessee further covenants and agrees that on or before the ____ day of ____, it will commence at its own expense and without cost to the Lessor to construct and build the development referred to in paragraph (13) and that it will complete the said development on or before the ____ day of ____, 19__.

Paragraph (15) Approval of Plans:

The Lessee covenants and agrees that before commencing any construction on the demised premises it will submit its plans for the foundations, supporting columns, buildings and structures to the Commissioner of Property of the Lessor and to the General Manager of Operations for the Toronto Transit Commission for approval and no construction shall be commenced without such approvals. If the Lessee at any time wishes to make additions, reductions, variations or changes in the buildings or structures, either during or after the construction thereof, no such additions, reductions, variations or changes shall be commenced without the approval of the Lessor, which approval may not be unreasonably withheld or delayed provided, however, that normal repairs and tenant alterations made by the Lessee shall not require the approval of the Lessor as aforesaid.

Paragraph (16) Subway Operation and Restoration

The Lessee agrees that all buildings and structures and the works thereof shall be constructed on the demised premises in such a manner as will not interfere with the operation of the subway and that upon the completion of construction all areas of the subway shall be restored to an equivalent standard of fire protection, safety, paving, ventilation and drainage as presently exists.

Paragraph (17) Interference with Subway Operations:

The Lessee covenants and agrees that it will not erect or construct any foundations, supporting columns, building or structure in whole or in part on any part of the demised premises, or substantially alter, repair, replace any supporting columns, foundations, building or structure so erected or constructed upon the said lands, in any manner so as to interfere with utility easements or with the use of such lands by the Lessor and the Toronto Transit Commission for the operation of the subway or any of the works thereof, nor shall any foundation, supporting column, building or structure be placed so that any part of the load thereto or therefrom shall bear directly or indirectly upon any utility easement or on the subway or any of the works thereto, in such manner that the use, maintenance, ventilation, suitability or safety of the said utility easements and the subway or any other works thereof shall in any manner be endangered or interfered with.

Paragraph (22) Zoning Compliance:

The Lessee agrees that the buildings and structures to be erected on the said demised lands and all uses thereof shall comply with the zoning and building by-laws of the area municipality in which the demised premises are situate and that it shall be the responsibility of the Lessee to obtain such building permits as may be required by the said by-laws and if necessary to have such by-laws amended. If the proposed use or development of the demised premises does not comply with the existing zoning, the Lessee may, if he is unable to obtain the necessary zoning amendments, terminate the lease at the end of the first eighteen months of the original term on six months' notice in writing to the Lessor and thereupon the balance of the prepaid rent shall be refunded, less interest paid thereon.

Paragraph (28) Noise and Vibration:

The Lessee for itself, its successors and assigns, and sub-tenants, agrees to hold the Lessor and the Toronto Transit Commission harmless from all claims arising from noise or vibration in, of and to the said demised lands and air rights resulting from the operations of the Toronto Transit Commission.

Paragraph (31) Use of Adjacent Lands:

The Lessor reserves its right to use or develop any of its lands or air rights immediately adjoining the demised lands and air rights in any manner it sees fit and the Lessee agrees to co-operate with the Lessor in this regard.

Paragraph (42) Vesting of Buildings on Termination:

It is hereby agreed between the parties hereto that upon the termination of this lease or, if renewed, upon termination of the renewal, the buildings and structures erected on the demised lands shall become the property of the Lessor.

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